6. EXAMPLE RUNS

This section contains three example runs to illustrate how to make the best use of the QUAL2E Windows interface. The example runs were selected in an attempt to exercise the major portions of the QUAL2E interface. A matrix of QUAL2E interface with the various runs is shown in Table 6.1. The QUAL2E interface generates five different input files. For a base QUAL2E run, a RUN file is required; an observed DO file is needed when there are observed data; a CLI file is applied if there are data for quasi-dynamic (i.e., diurnal variations) simulations. For an uncertainty analysis run, an UNS file and a VAR file are needed in addition to a RUN file and/or a DO file. The first example is designed to simulate three water quality constituents: temperature, dissolved oxygen (DO), and ultimate carbonaceous BOD (CBODU) in a steady state mode with metric units. The second example includes a QUAL2E uncertainty analysis in which all five input files are generated by the interface with U.S. units. The last example performs a quasi-dynamic/diurnal simulation for most of the conventional pollutants.

These examples were obtained from EPA and demonstrate the potential applications of the QUAL2E/QUAL2EU model. The interface runs can be checked using the input files supplied by EPA along with the distribution package for QUAL2E. The example input files prepared for testing the QUAL2E Windows interface and corresponding files used for QUAL2E are listed in Table 6.2.

6.1 Example 1 - Dirty River Reaches DO/BOD/TEMP Simulation

This is an example of the QUAL2E model's ability to simulate three water quality constituents: temperature, dissolved oxygen (DO), and ultimate carbonaceous BOD (CBODU) in a steady state mode with metric units. A sketched stream system for a study area is shown in Figure 6.1. The network connections and computational elements for Example 1 are shown in Figure 6.2. The data that are presented consist of the following:

A. Flow data

From gaged data and drainage area ratio analysis, the following information was developed:

1. Reach 1   Flow at the headwater of Dirty River = 0.5 m^3/s
2. Reach 1   Point source discharge from the STP = 0.48 m^3/s
3. Reach 1   Incremental flow in Dirty River above junction with Clear Creek = 1.241 m^3/s
4. Reach 2   Reservoir release into Clear Creek = 0.38 m^3/s
5. Reach 2   Incremental flow in Clear Creek above junction with Bull Run = 0.388 m^3/s
6. Reach 3   Flow at headwater of Bull Run = 0.14 m^3/s
7. Reach 3   Incremental flow in Bull Run = 0.003 m^3/s
8. Reach 4   Incremental flows = 0.015 m^3/s
9. Reach 5   Incremental flows = 0.015 m^3/s
10. Reach 6   Incremental flows = 0.108 m^3/s
11. Reach 6   Withdrawal at the diversion = 0.5 m^3/s

Figure 6.3 (a), (b), and (c) show the screen where these data are entered.

B.   Hydraulic data

These data come from past gaged data and special survey data on velocities and depths.

1. Dirty River   Vel = 0.25 $Q^{0.30}$, Depth = 0.44 $Q^{0.55}$

2. Clear Creek   Vel = 0.38 $Q^{0.37}$, Depth = 0.51 $Q^{0.61}$

3. Bull Run   Vel = 0.28 $Q^{0.35}$, Depth = 0.48 $Q^{0.58}$

4. Pond   Vel = 0.065 $Q^{0.85}$, Depth = 1.1 $Q^{0.05}$

Table 6.1 Example Run Matrix for QUAL2E Windows Interface

Component	EXAMPLE RUN		
QUAL2E	1	2	3
Simulation			
Steady state	■	■	
Dynamic			■
Water quality constituents			
Temperature	■	■	■
CBODU	■	■	■
DO	■	■	■
Algae		■	■
Phosphorus		■	
Nitrogen		■	■
Fecal coliform			■
Non-conservative			
Conservative			
Observed DO data	■	■	
Temperature correction factors			
Default		■	
User-defined	■		■
Climatological data			
Reach variable			
Global	■	■	■
Functional data			
Headwaters	■	■	
Point sources/withdrawals	■	■	
Dams	■		
Flow augmentation			
Downstream condition		■	
Trapezoidal channels			
Uncertainty analysis			
Sensitivity			
First order error		■	
Monte Carlo			
Units			
U.S. units		■	
Metric	■		■

Table 6.2 Example Input Files with QUAL2E Windows and QUAL2E

| Example	Type of File	QUAL2E Interface	QUAL2E Model
	QUAL2E Windows Interface Input	QAL2E001.INP	
	QUAL2E Input	QAL2E001.RUN	WRKSHOP1.DAT
	Measured Dissolved Oxygen Input	QAL2E001.DO	WRKSPDO.DAT
2	QUAL2E Windows Interface Input	QAL2E002.INP	
	QUAL2E Input	QAL2E002.RUN	WTHBASE1.DAT
	Measured DO Input	QAL2E002.DO	WTHDO.DAT
	Uncertainty Input	QAL2E002.UNS	WTHUAF1.DAT
	Variance uncertainty Input	QAL2E002.VAR	WTHINV.DAT
3	QUAL2E Windows Interface Input	QAL2E003.INP	
	QUAL2E Input	QAL2E003.RUN	DIURNL.DAT
	Climatology Input	QAL2E003.CLI	DINTMP.DAT
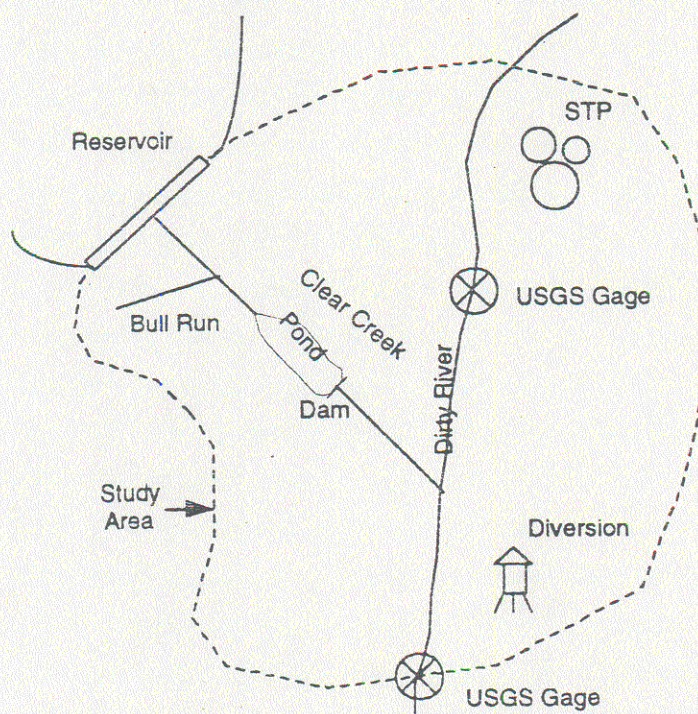
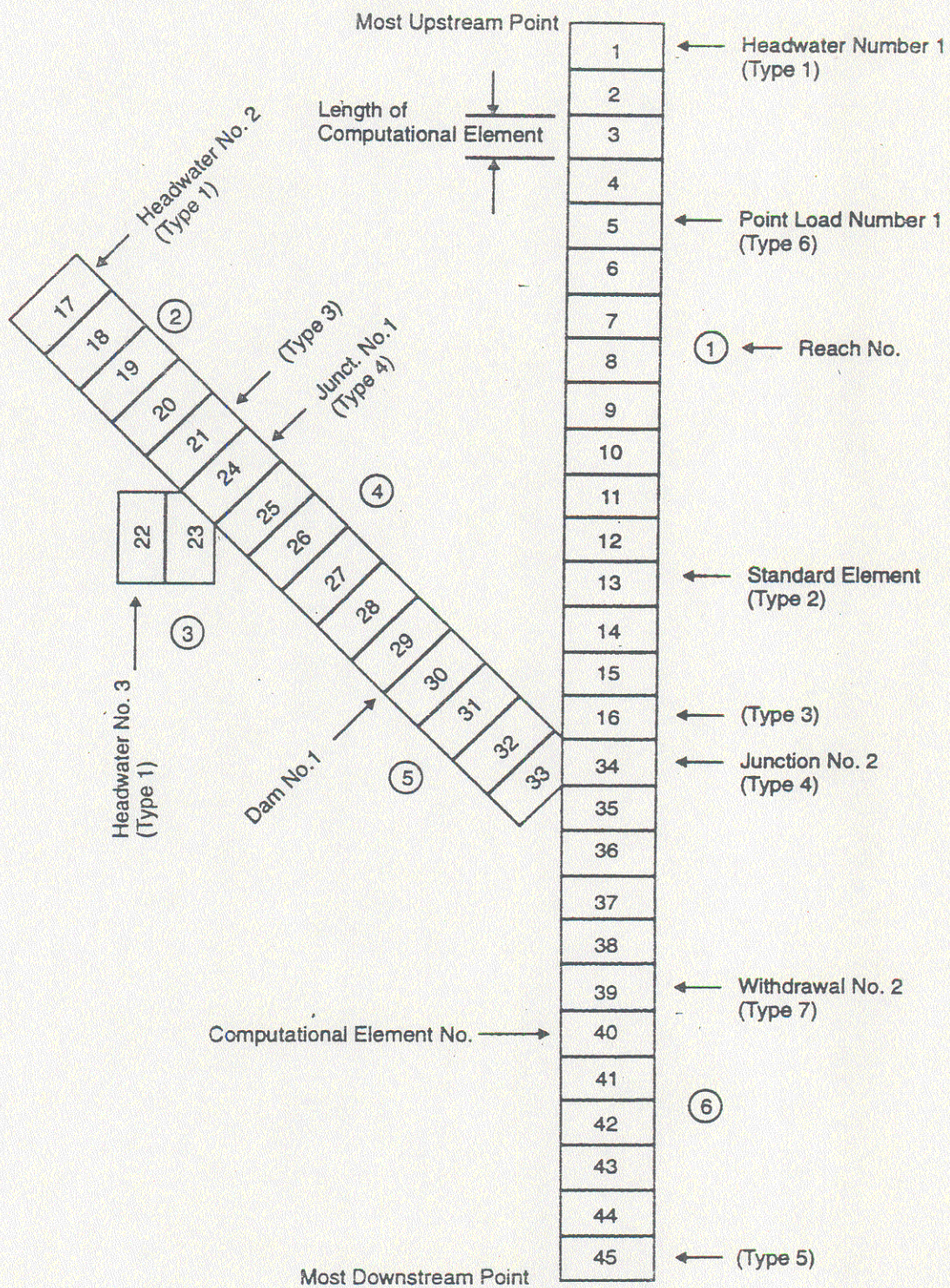Figure 6.1 Sketched Stream System for a Study Area.

Figure 6.2 Computational Elements in Example 1.

(a)

File   Edit   Tool   Utilities   Import   Help

| Help | | Next | Back | Top | Index | | Run | Restore | | Graphics | Calc |

Incremental Inflow

FLOW [m3/s] [1]: 0.261

REACH NO.	FLOW [m3/s]	TEMP [C]	DO [mg/l]	BOD [mg/l]	CONS #1	CONS #2	CONS #3	NO
1	0.261	18.	1.	20.	0	0	0	
2	0.008	18.	1.	5.	0	0	0	
3	0.003	18.	1.	5.	0	0	0	
4	0.015	18.	1.	5.	0	0	0	
5	0.015	18.	1.	5.	0	0	0	
6	0.108	18.	1.	50.	0	0	0	

(a)

(b)

File   Edit   Tool   Utilities   Import   Help

| Help | | Next | Back | Top | Index | | Run | Restore | | Graphics | Calc |

Headwater Source Data

FLOW [m3/s] [1]: 0.5

HEADWATER NAME	FLOW [m3/s]	TEMP [C]	DO [mg/l]	BOD [mg/l]	CONS #1	CONS #2	CON
DIRTY RIVER	0.5	22.	8.3	1.7	0	0	
CLEAR CREEK	0.38	15.	0	2.	0	0	
BULL RUN	0.14	21.	5.	20.	0	0	

(b)

Figure 6.3 Entering Data in QUAL2E Windows Interface Screens.

File Edit Tool Utilities Import Help

Help   Next Back Top Index   Run Restore   Graphics Calc

Point Loads and Withdrawals

NAME [1]: RIVR CTY STP

REACH NO.	ELE NO.	TYPE	NAME	TREAT [%]	FLOW [m3/s]	
1	5	Point source	RIVR CTY STP	0	0.48	
6	6	Withdrawal	DIVERSION	0	-0.5	

(c)

QUAL2E [QAL2E001.INP]

File Edit Tool Utilities Import Help

Help   Next Back Top Index   Run Restore   Graphics Calc

Hydraulic Data

DISPER CONST [1]: 60.

REACH NO.	DISPER CONST	Q COEFF VEL	Q EXP VEL	Q COEFF DEPTH	Q EXP DEPTH	MANNING	SIDE SLOPE 1 (m/m)
1	60.	.25	.30	.44	.55	.04	
2	60.	.38	.37	.51	.61	.04	
3	120.	.28	.35	.48	.58	.04	
4	6000.	.065	.95	1.1	.05	.04	
5	200.	.38	.37	.51	.61	.04	
6	400.	.22	.33	.43	0.38	.04	

(d)

Figure 6.3 (continued)

File   Edit   Tool   Utilities   Import   Help

Help   Next   Back   Top   Index   Run   Restore   Graphics   Calc

Dam Reaeration

ADAM COEFF (1):   1.25

REACH NO.	ELE NO.	ADAM COEFF	BDAM COEFF	% FLOW OVER DAM	HEIGHT DAM (m)
5	1	1.25	1.1	1.	3.

(e)

File   Edit   Tool   Utilities   Import   Help

Help   Next   Back   Top   Index   Run   Restore   Graphics   Calc

BOD and DO Reaction Rate Constants

BOD DECAY [1/day] (1):   0.6

REACH NO.	BOD DECAY [1/day]	BOD SETTLING [1/day]	SOD RATE [g/m2-day]	TYPE REAERATION
1	0.6	0	0.5	Thackston and Krenkel
2	0.6	0	0	O'Connor and Dobbins
3	0.6	0	0	O'Connor and Dobbins
4	0.6	0.1	1.	O'Connor and Dobbins
5	0.6	0	0	O'Connor and Dobbins
6	0.6	0	0.5	Thackston and Krenkel

(f)

Figure 6.3   (continued)

QUAL2E [QAL2E001.INP]

File   Edit   Tool   Utilities   Import   Help

Help   Next Back Top Index   Run Restore   Graphics Calc

BOD and DO Reaction Rate Constants

BOD DECAY [1/day] [1]:   0.6

REACH NO.	BOD DECAY (1/day)	BOD SETTLING (1/day)	SOD RATE (g/m2-day)	TYPE REAERATION
1	0.6	0	0.5	Thackston and Krenkel
2	0.6	0	0	O'Connor and Dobbins
3	0.6	0	0	O'Connor and Dobbins
4	0.6	0.1	1.	O'Connor and Dobbins
5	0.6	0	0	O'Connor and Dobbins
6	0.6	0	0.5	Thackston and Krenkel

(g)

QUAL2E [QAL2E001.INP]

File   Edit   Tool   Utilities   Import   Help

Help   Next Back Top Index   Run Restore   Graphics Calc

Temperature Correction Factors

BOD

Decay   1.047

Settling   1.024

DO

Reaeration   1.0159

SOD uptake   1.060

Nitrogen

Phosphorus

Algae

Non-conservative

(h)

Figure 6.3 (continued)

File   Edit   Tool   Utilities   Import   Help

| Help | | Next | Back | Top | Index | | Run | Restore | | Graphics | Calc |

Geographical and Climatological Data

Latitude (deg)   42.5
Longitude (deg)   83.3
Standard meridian (deg) 75.
Basin elevation (m)   150
Dust attenuation coeff.   0.13

Evaporation coefficient
AE [(m/hr)/mbar]   0
BE [(m/hr)/(mbar-m/s)]   5.55e-6

Temperature correction factors
○ Default
● User specified

Climatological Data
○ Reach variable temp.
● Global values
Climatological file   [   ]

Output Print
☐ Summary
☒ Climatological data printout

☒ DO and BOD plot
Number of DO/BOD plots   2
Observed Dissolved Oxygen file   WRKSHOP1.D

(i)

Figure 6.3 (continued)

5. Dirty River below Clear Creek
   Vel = 0.22 $Q^{0.3}$, Depth = 0.43 $Q^{0.48}$

6. Dam information for reaeration:

   - All of the flow passes over the crest of the dam.

   - The dam has a height of 3 meters and acts as a weir with free-falling flow.

   - Assume a=1.25 and b=1.1.

7. Manning's n is assumed constant for all reaches, with a value of 0.04.

Hydraulic data are entered on the screens shown in Figure 6.3 (d) and (e).

C. Water quality data

   1. Incremental inflow water temperature=18.0°C
   2. Incremental DO = 1.0 mg/l for all reaches
   3. Incremental CBODU

      = 5.0 mg/l for Clear Creek and Bull Run
      = 20 mg/l for Dirty River above Clear Creek
      = 50 mg/l for Dirty River below Clear Creek

   4. Headwater quality

      Dirty river: DO = 8.3 mg/l, CBODU = 20.0 mg/l, T = 22.0°C

      From reservoir: DO = 0.0 mg/l, CBODU = 10.0 mg/l, T=15.0°C

      Bull Run: DO = 5.0 mg/l, CBODU = 5.0 mg/l, T = 21.0°C

These water quality data are entered on the same screens as those for flow data, Figures 6.3 (a) and (b).

D. Sediment oxygen demand

   Samples showed the following:

   1. 0.5 gm/m3-day for Dirty River above Clear Creek

2. 1.0 gm/m2-day for Pond

3. 0.5 gm/m2-day for Dirty River below Clear Creek

Sediment oxygen demand data are entered on a screen titled as "BOD and DO reaction rate constants," shown in Figure 6.3(f).

E. Point source (or discharge) and withdrawal data
   1. Point source: Q = 0.48 m³/s, DO = 4.0 mg/l, CBODU = 5.0 mg/l, T = 25.0°C

   2. Withdrawal: Q = 0.5 m³/s

These data are entered on the screen shown in Figure 6.3(c).

F. Reaction rates

   1. The bio-oxidation rate for CBODU was determined from long-term BOD tests:

      - For all reaches of the Dirty River, K_1 = 0.6 per day.
      - For all reaches of Clear Creek and Bull Run, K_1 = 0.6 per day.

   2. The BOD settling rate is zero, except in the pond where it is 0.1 per day.

   3. The reaeration coefficient is to be calculated by the O'Connor and Dobbins method (Option 3) for all reaches of the Clear River and Bull Run, and it is to be computed by the Thackston and Krenkel method (Option 5) in all reaches of the Dirty River.

   4. Temperature adjustments to the reaeration rate coefficient are to be made using the O'Connor and Dobbins theta value (1.0159).

Decaying and settling rates of biochemical oxygen demand are entered on the same screen as for SOD. Temperature adjustments to the rate coefficients are made in the Temperature Correction Factors screen, shown in Figure 6.3(h).

G. Temperature information

   1. Evaporation coefficient: Use Lake Hefner equation AE = 0.0 and BE = 0.0000056.

2. Dust attenuation coefficient = 0.13

3. Location of basin: metropolis; longitude = 83.3, standard meridian = 75, Latitude = 42.5, Basin elevation = 150 m ·

4. Local climatology: cloudiness = 0.25, Dry bulb temperature = 25.0°C, wet bulb temperature = 20.0°C, atmospheric pressure = 980 mbar, wind speed = 2.5 m/s.

These data are provided in the Geographical and Climatological data screen, as shown in Figure 6.3 (i).

The steps that you must follow for this example are explained in detail below:

STEP 1. Select the QUAL2E Windows interface by clicking twice on the QUAL2E icon.

STEP 2. Select an existing file called QAL2E001.INP in the QUAL2E interface by selecting the File option, followed by the Open option. The file will be loaded into the QUAL2E interface. A total of 24 screens are available to you when you click on the INDEX button that illustrates the overall structure of the input file. (The other screens are grayed out due to choices made in the sample run.) Normally, QUAL2E requires you to provide information on the reach system of the study area, simulation control variables, functional data, and climatology data. Since you are retrieving an existing input file, you are not required to do this.

STEP 3. Examine the input file in detail and familiarize yourself with it by using the NEXT and BACK buttons to move through the screens and the HELP button to obtain general and detailed information about the interface and specific prompts. Areas on which you should focus are given below:

How to describe a complete stream system
The first three screens are most important because the majority of the data on the following screens are dependent upon the information given by Screens 1-3. First, you must enter the number of reaches in

the system on Screen 1. If you do not enter this number, the interface will not let you access other screens. Then, you are required to give the reach name, beginning and ending river miles or kilometers for each reach, an indication of the headwaters, and an element length. The sequence of the reaches that you provide on Screen 2 should always be entered from the most upstream reach to the most downstream reach. The element length is a computational unit that has to be divisible by all reaches. The information on Screen 2 will be used to display the reach connections. Remember that river reaches and computational elements are the basis of most data input. It is suggested that you draw a reach network system before entering the data.

How to use the unit conversion
The unit selection appears on the first screen. The QUAL2E interface permits two sets of units: metric and U.S. units. Metric units, for example, are selected for Example 1 (QAL2E001.INP). If you want to change to U.S. units, you can simply click on U.S. units. Then a windows message will ask you whether you would like to convert all the variables from metric to U.S. units or just change the unit titles for the variables without converting the variables' values. At this point, you need to choose YES, NO, or Cancel.

Select YES to convert all the variables from one unit to another. Select NO to change the unit titles for the variables' required units. Select Cancel to return to the original unit selection.

Certain important screens are detailed below.

Screens 1
The stream simulation is set to be steady state. Metric units are chosen for the model input and output. Since there is no uncertainty analysis involved for this example, Screens 21-24 are grayed. Similarly, Screen 10 is grayed because flow augmentation is not applied. The number of reaches in the stream system is six.

Screen 4
This screen lists 15 water quality constituents that can be simulated. Select the constituents that you want to simulate. Three constituents are selected in Example 1.

Screen 5
Screen 5 defines the basin geographic information, temperature correction option, climatological data, and DO/BOD plot. You can define the temperature coefficients or use the model default values. Climatological data can be varied from one reach to another or specified as constant values for all reaches. The DO/BOD plot is an option for the model input. It is applied when a user has observed DO data and wants to calibrate the model to compare the predicted DO with the observed DO. You can either select an existing DO file, which contains the data, or indicate the number of points for each BOD/DO plot and enter the measured data on Screen 7. Example 1 chooses to select an existing DO input file, called WRKSHOP1.DO, and the data can be seen on Screen 7.

STEP 4. Submit the QUAL2E interface input file to the QUAL2E model for execution by clicking on the RUN button. An icon appears at the bottom of the screen with the words QUAL2E MODEL EXECUTION. When the processing is complete, a message appears: "QUAL2E completed. Do you want to view the output file?" Select OK to view the output using the default editor. After viewing the tabulated output, press ALT-F and X in sequence to return to the QUAL2E main menu.

STEP 5. You might also want to plot a QUAL2E graphic. Click on the Graphics button. Select a QUAL2E output file (e.g., QAL2E001.OUT). Once you have chosen the QUAL2E output, click on the Reaches button to view a network diagram of the stream network and computational elements. This plot should be similar to Figure 6.2. If you want to make a hard copy for the plot, you can use the Print option to send the plot directly to the

printer or use the Edit and Copy/Paste option to place the graph in another Windows package such as the Clipboard.

To graph flow vs. distance, click on flow vs. distance as the type of graph, and then define the starting reach as 1 and ending reach as 6. Click the Run button to view the graph.

To graph water quality constituents, select water quality constituents as the type of graph and define the starting and ending reaches. When you click on Run, a Pollutant Selection screen will appear with a list of pollutants. Select the pollutants you want to plot and click on Run again. A window will list all the graphs in the default directory. Select the graphs you would like to see and choose OK. QUAL2E Graphics allows you to draw up to four graphs on the same screen. To do this, you should create different graphs and then select up to four graphs that you want to see on one screen. An example QUAL2E graph is provided in Figure 6.4.

6.2   Example 2—Withlacoochee River QUAL2E and Uncertainty Analysis

This exercise demonstrates how to use the uncertainty analysis option. A QUAL2E base run is performed first, followed by an uncertainty run. The Withlacoochee River basin is located in Florida and is a simple reach system containing 11 reaches. Two point source loads are applied in Example 2. Six water quality parameters are simulated: temperature, BOD, algae, DO, phosphorus, and nitrogen. In the uncertainty analysis, the First Order Error analysis is used and a default input perturbation of 5 percent is used for computing sensitivity coefficients. In addition, the variance of each input variable is given on Screen 23.

The steps that you must go through for this example run are explained below:

STEP 1.   Select the QUAL2E Windows Interface option from the main QUAL2E menu. Choose FILE option, followed by the Open option. A list of QUAL2E input files will appear. Select a QUAL2E interface file, QAL2E002.INP. Since an uncertainty analysis is involved, you will see Uncertainty analysis is selected on Screen 1.

STEP 2.   Familiarize yourself with this input file and the screens in the QUAL2E option by moving through the screens using the NEXT, BACK, or INDEX option.

You can easily change a number of rows in a column using a feature available in array screens of the QUAL2E Windows interface (screens where the same variable requires one or more rows of entries). If you click on the variable in these screens, you will be able to add, subtract, multiply, or divide for any single value or range of values for this variable. You can therefore change all zero values for a variable to a single default by adding the default value that you want to all the zero values in the array.

STEP 3.   Submit the QUAL2E input file to the QUAL2E model for execution by clicking on the RUN button. An icon will appear at the bottom of the screen with the words QUAL2E MODEL EXECUTION. When the processing is complete, the output will be shown in the default output file viewer (i.e., default editor). View the output carefully.

STEP 4.   If you want to draw a QUAL2E graphic, click on the Graphics Button. A QUAL2E graphic for Example 2 is shown in Figure 6.5. To exit from QUAL2E, press ALT-F for File and then X for Exit.

6.3   Example 3—Dynamic/Diurnal Simulation

This example simulates a simple river system with a total of five reaches and nine water quality constituents for a QUAL2E run. This is a dynamic/diurnal simulation with a total simulation of 60 hours and a time step of 1 hour. Since it is a dynamic simulation, the climatological data are required at regular time intervals over the course of the simulation. There is an existing climatological input file available for input. The input file, DIURNAL.CLI, can be read
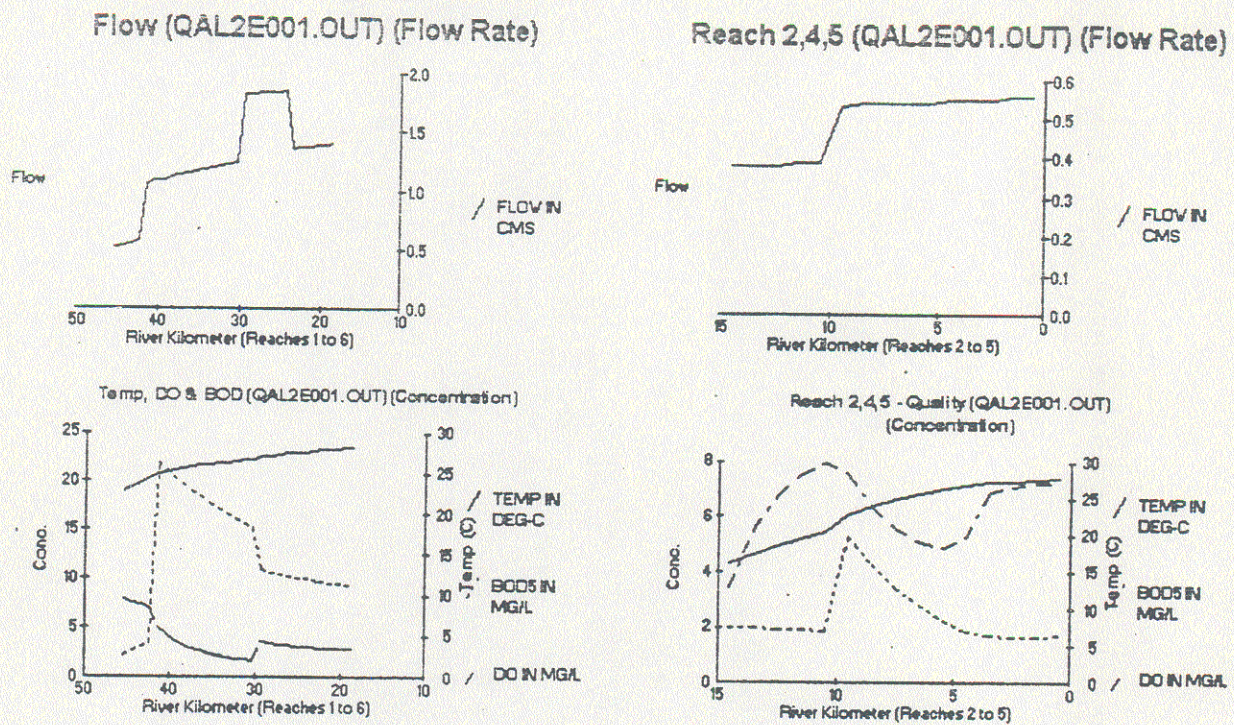
Flow (QAL2E001.OUT) (Flow Rate)

Reach 2,4,5 (QAL2E001.OUT) (Flow Rate)

Temp, DO & BOD (QAL2E001.OUT) (Concentration)

Reach 2,4,5 - Quality (QAL2E001.OUT)
(Concentration)

Figure 6.4 QUAL2E Graph from Example 1.

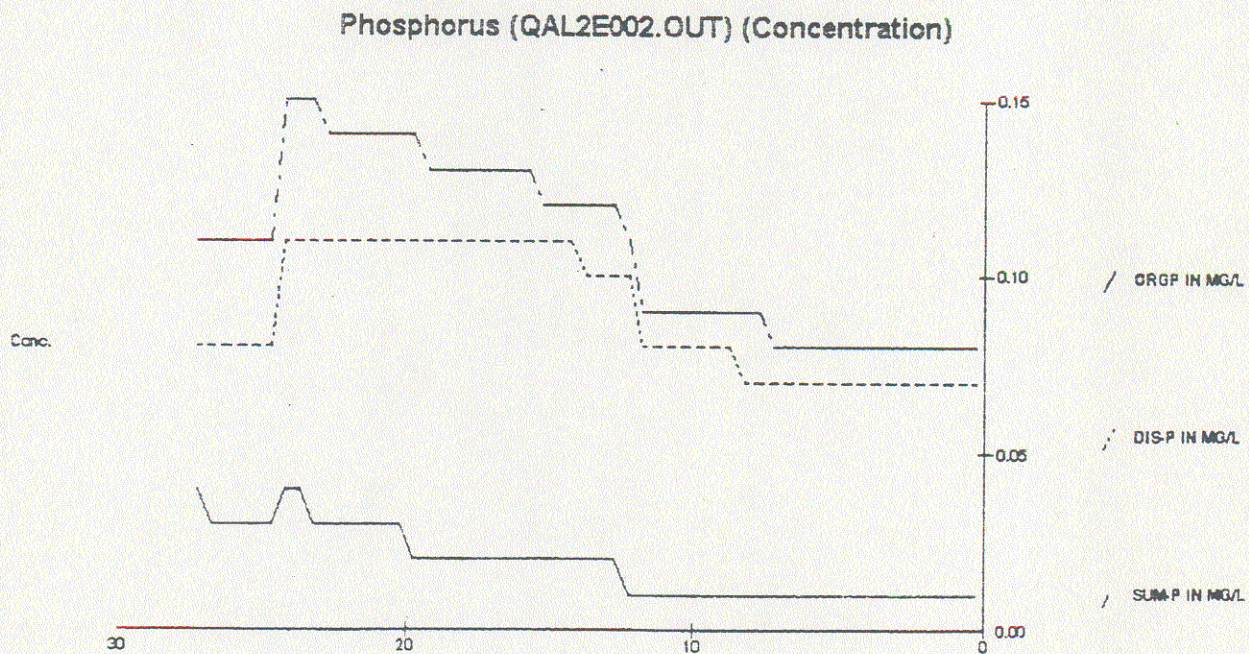Phosphorus (QAL2E002.OUT) (Concentration)

Figure 6.5 Phosphorus Concentration vs. Distance.

through the Import function. In this example, the downstream boundary conditions are known and specified in the interface input file. The model solution will, therefore, be constrained to match the known concentrations.

The steps that you must follow for this example are explained in detail below:

STEP 1. Select the QUAL2E Windows Interface option from the main QUAL2E menu. Next, open the QUAL2E interface file, QUAL2E003.INP. The file will be loaded into the QUAL2E interface. Move through the screens and familiarize yourself with this option. Use the help information available to you through the HELP button to answer any questions you might have about any prompts.

STEP 2. Go to Screen 3 for the computational element set-up. The entire system con-

sists of a total of five reaches, three headwaters, two junctions, and one downstream element. There are no point source loads or withdrawals in the system, so the fields on Screen 3 that are not grayed represent the standard elements.

STEP 3. You may use the IMPORT function on the main menu bar at the top of the QUAL2E window. When you select the IMPORT option, you will see a list of five types of input files. Choose the CLI file type and select the DIURNL.CLI file from the list presented. The climatological data with 3-hour intervals will be entered on Screen 20. Click INDEX to move to Screen 20 and check the climatic data.

STEP 4. Next, click on the RUN button. The output file will be displayed when it is ready. If you want to plot the model results, click on the Graphics button.